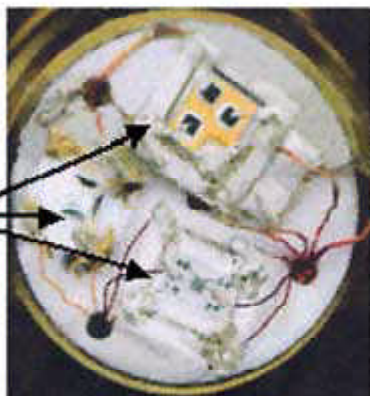


# High-Temperature Gas Sensor Array (Electronic Nose) Demonstrated

The ability to measure emissions from aeronautic engines and in commercial applications such as automotive emission control and chemical process monitoring is a necessary first step if one is going to actively control those emissions. One single sensor will not give all the information necessary to determine the chemical composition of a high-temperature, harsh environment. Rather, an array of gas sensor arrays--in effect, a high-temperature electronic "nose"--is necessary to characterize the chemical constituents of a diverse, high-temperature environment, such as an emissions stream. The signals produced by this nose could be analyzed to determine the constituents of the emission stream. Although commercial electronic noses for near-room temperature applications exist, they often depend significantly on lower temperature materials or only one sensor type. A separate development effort necessary for a high-temperature electronic nose is being undertaken by the NASA Glenn Research Center, Case Western Reserve University, Ohio State University, and Makel Engineering, Inc. The sensors are specially designed for high-temperature environments.

A first-generation high-temperature electronic nose has been demonstrated on a modified automotive engine. This nose sensor array was composed of sensors designed for high-temperature environments fabricated using microelectromechanical-systems- (MEMS-) based technology. The array included a tin-oxide-based sensor doped for nitrogen oxide ( $\text{NO}_x$ ) sensitivity, a SiC-based hydrocarbon ( $\text{C}_x\text{H}_y$ ) sensor, and an oxygen sensor ( $\text{O}_2$ ). These sensors operate on different principles--resistor, diode, and electrochemical cell, respectively--and each sensor has very different responses to the individual gases in the environment. A picture showing the sensor head for the array is shown in the photograph on the left and the sensors installed in the engine are shown in the photograph on the right. Electronics are interfaced with the sensors for temperature control and signal conditioning, and packaging designed for high temperatures is necessary for the array to survive the engine environment.

Three MEMS-based chemical sensors installed in sensor holder for testing

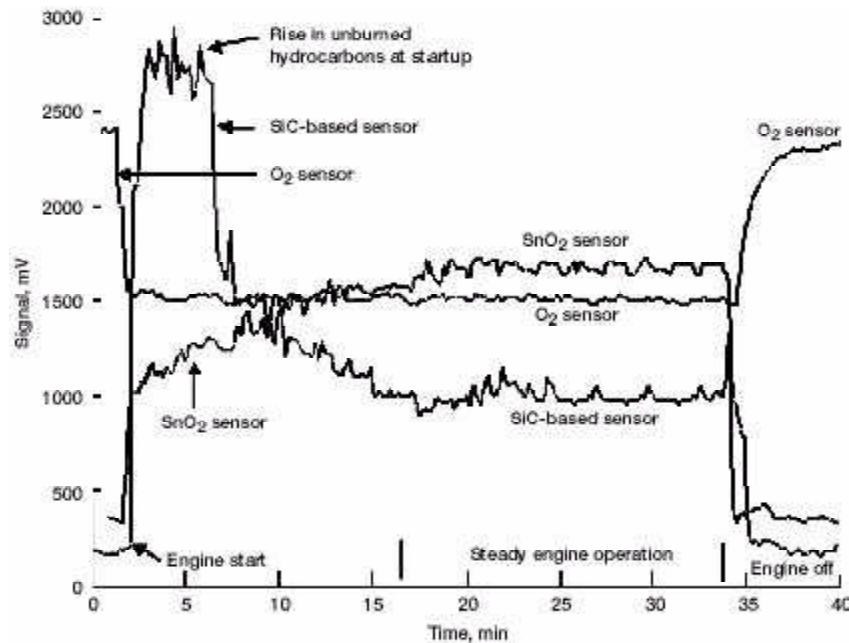


Sensors installed in automotive engine



*Left: Prototype high-temperature electronic nose array sensor head. Right: Sensors installed in engine.*

The graph shows the individual sensor responses during the initial start of the engine, during a warm-up period, during a steady-state operation period, and at the engine turnoff. The sensors were operated at 400 °C, whereas the engine operating temperature was 337 °C. Each sensor has a different characteristic response. The oxygen sensor shows a decrease in O<sub>2</sub> concentration, whereas the NO<sub>x</sub> and C<sub>x</sub>H<sub>y</sub> concentrations (as measured by the tin oxide and SiC sensors, respectively) increase at startup. The hydrocarbon concentrations decrease as the engine warms to steady-state, while the NO<sub>x</sub> concentration increases before stabilizing. The O<sub>2</sub>, NO<sub>x</sub>, and C<sub>x</sub>H<sub>y</sub> concentrations all return to their startup values after the engine is turned off. These results are qualitatively consistent with what would be expected for this type of engine. They also show the value of using sensors with very different response mechanisms in an electronic nose array: the information provided by each sensor was unique and monitored a different aspect of the engine's chemical behavior. Further work is planned to include the addition of more sensors and pattern recognition software for sorting out the responses of the various sensors. Neural network processing will be used to integrate and interpret this information to more accurately determine the chemical signatures of harsh, high-temperature environments. The high-temperature electronic nose integration work and demonstration was funded by the Glennan Microsystems Initiative.



*Response of a sensor array composed of a tin-oxide-based sensor (doped for NO<sub>x</sub> sensitivity), an oxygen sensor, and a SiC-based hydrocarbon sensor in an engine environment.*

Graph of the signal versus the time showing data for SnO<sub>2</sub> sensor, O<sub>2</sub> sensor, and SiC-based sensor and indicating engine start, rise in unburned hydrocarbons at startup, steady engine operation, and engine off.

**Find out more about this research:**

Glenn's gas sensor research <http://www.grc.nasa.gov/WWW/chemsensors/>

Glennan Microsystems <http://www.glennan.org/>

## **Bibliography**

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